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Effects of Reservoir Operations on Fisheries

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Purpose

The significance of reservoir operations on fisheries was studied over 2 years under the Natural Resources Research Program (NRRP). Two major topics were addressed to (1) rapidly assess the recreational fisheries potential of reservoirs to support the Regional Recreation Demand Model (RRDM) and (2) evaluate effects of reservoir operations on fisheries. The goals were to define operations benefiting warmwater fisheries, identify important biotic and abiotic factors affecting fisheries, define the mechanisms by which operations affect fisheries, conduct a case study to validate operations benefiting fisheries, and provide guidance to resource managers on operations that could benefit fisheries within authorized project purposes. Unfortunately, most of these goals were not met because the work unit was terminated before a case study was conducted.

Background

Recreational fishing or angling is an important pastime in the United States. During 1991, an estimated 35,600,000 Americans fished a total of 511 million days spending approximately $24 billion (U.S. Fish and Wildlife Service 1993). Of this total, 20,900,000 Americans fished 221 million days in lakes and reservoirs which made up approximately 69 percent of all angling, both fresh and saltwater, in the United States (USFWS 1993). The U.S. Army Corps of Engineers played a large role in this recreational activity. The Corps operates almost 450 reservoirs, is the second largest provider of recreational opportunities in the United States, and is the largest provider of water-based recreation in the United States (U.S. Army Corps of Engineers 1990). Because operations can significantly affect fisheries (Ploskey 1986), activities of the Corps in managing water levels can have a large national impact, either negatively or beneficially, on both the fishery resource and recreation.

Measures of Fisheries Potential for Use in the Regional Recreation Demand Model

A method to rapidly assess fisheries potential within reservoirs was needed as a parameter input to the RRDM. The RRDM is a predictive tool, developed by the NRRP, to estimate changes in recreational visits and economic benefits resulting from, and related to, resource characteristics, visitor demographics, recreational substitutes, and available facilities (Ward and others, in press). The morphoedaphic index (MEI) (Ryder 1965) is used in the RRDM as a measure of fisheries potential. MEI is defined as the total dissolved solids divided by the mean depth of the reservoir or lake. The index was initially developed to estimate potential yield of game and commercial fishes in large Canadian lakes, but is also used in predicting yields in U.S. reservoirs (Jenkins 1967). "Yield," as predicted using MEI, can be influenced by nonbiological factors such as fishing gear, species preference, or distance to population centers. Thus, other measures may be more appropriate. The discussion that follows compares MEI with two other measures of fisheries potential based upon standing crop of sportfishes and recommends a measure of fisheries potential for use in the RRDM.

Approach and Findings

Fisheries potential in 24 Corps of Engineers reservoirs in the Nashville, Sacramento, and Little Rock Districts was estimated using sportfish standing crop derived from rotenone sampling and predictive equations using physical data (that is, climatic, water quality, and morphometric attributes). Most information used to determine sportfish standing crops came from the National Reservoir Research Database developed by the USFWS. This database was a compilation of physical data and rotenone samples that were performed by natural resource agencies. Predictive equations developed from these data (Ploskey and others 1986) were used to make estimates of the sportfish standing crop. Rotenone data for 20 of the 24 study reservoirs came from this Reservoir Research Database.

Categories using sportfish standing crop based upon rotenone samples were used to characterize the fisheries potential of study reservoirs. These categories were developed from a subset of the National Reservoir Research Database which included 253 reservoirs in the southern and midwestern United States. This subset was chosen as being representative of most reservoirs where rotenone has been used for sampling fish populations. Categories of fisheries potential were developed by dividing sportfish standing crop from the 253 reservoirs into quartiles. These categories were deemed to be broad enough to accommodate natural variation in standing crop while indicating different ranges of fisheries potential typically found in U.S. reservoirs. The categories are as follows:

Category	Standing Crop of Sportfish
1	<51 pounds per acre
2	52 to 77 pounds per acre
3	78 to 116 pounds per acre
4	117 to 351 pounds per acre

Similarly, MEI values from the 253 reservoirs were divided into quartiles:

Category	MEI
1	0.20 to 1.85
2	1.86 to 3.49
3	3.50 to 8.90
4	8.91 to 33.92

MEI-based categories agreed with those determined from rotenone sampling in six of 21 reservoirs and those determined from predictive equations in six of 23 reservoirs (Table 1). Predicted standing crops corresponded with rotenone sampling about 50 percent of the time (Table 1).

Trade-offs Between Methods

Each method has advantages and disadvantages when used in predicting fisheries potential of Corps of Engineers reservoirs. The MEI is simple and inexpensive, requiring only total dissolved solids and mean depth. Conversely, acquiring standing crop information from rotenone or from predictive equations can be expensive or impossible. (Rotenone sampling is generally not feasible in northern climates.) Use of the MEI has both theoretical and practical limitations. MEI was originally developed to estimate yield and was later applied to biomass estimates. MEI use should be limited to reservoirs that are relatively similar in terms of chemical, physical, and climatic properties (Ryder and others 1974).

Recommendations

To date, fisheries potential defined using MEI has been used in the development of the RRDM. Serious doubts as to the efficacy of MEI-based measures of fisheries potential exist based upon the disagreement between MEI and sportfish standing crop categories shown in Table 1. Yield estimates may be affected by nonbiological factors, and standing crop estimates better approximate fishery resources available to anglers. If financial resources are sufficient, estimating fisheries potential using sportfish standing crop is recommended, preferably from rotenone sampling. If standing crop is estimated, predictive equations developed by Ploskey and others (1986) should be used because these equations are based upon regional data sets, consider other significant

Table 1. Ranking of the Recreational Fishing Potential of Corps of Engineer Reservoirs Using Predicted Sportfish Standing Crop, Mean Sportfish Standing Crop Using Rotenone Sampling, and Morphoedaphic Index (MEI)

Reservoir	Predicted Standing Crop	Rotenone Standing Crop	MEI
Beaver, AR	2	2	1
Bull Shoals, AR	2	2	2
Norfork, AR	2	2	2
Blue Mountain, AR	2	2	3
Dardanelle, AR	3	3	4
Greers Ferry, AR	2	3	1
Millwood, AR	1	4	3
Nimrod, AR	2	3	2
Ozark, AR	3	4	4
Pool 13, AR	3	3	4
Gillham, AR	1	3	1
Isabella, CA	2	na[1]	3
Pine Flat, CA	2	na	1
Cumberland, KY	2	1	1
Barkley, KY	2	2	3
Laurel, KY	2	2	2
Clearwater, MO	1	1	4
Table Rock, MO	2	3	4
Center Hill, TN	2	1	1
Dale Hollow, TN	2	1	2
Old Hickory, TN	1	2	3
Cheatham, TN	3	na	4
Cordell Hull, TN	1	1	3
Percy Priest, TN	na	2	4

[1]Indicates information is unavailable.

reservoir attributes, and are better predictors of fisheries potential than MEI (Oglesby 1982). These predictive equations represent a refinement over MEI (Jenkins 1982) but can be expensive to use because physical and chemical attributes must be measured for each reservoir. Measures of fisheries potential using sportfish standing crop should be tested in RRDM model development based on the following considerations: (1) will the model will be significantly improved by use of standing crop estimates and (2) are the model improvements using standing crop measures cost-effective?

Reservoir Operations and Fisheries

Many studies documenting effects of operations on fisheries exist; Ploskey (1986) performed one of the most thorough reviews considering over 350 articles. According to Ploskey and others, substantial water-level fluctuations can affect sportfish populations. In addition to magnitude of fluctuation, onset and duration of water-level fluctuations are important considerations in water-level management. A synthesis of the literature (Heman, Campbell, and Redmond 1969; Keith 1975; Wegener and Williams 1975; Groen and Shroeder 1978; Willis 1986; Ploskey 1986; Wright 1991) recommends operations that encourage strong year class production of sportfish. According to these studies, optimal operations are characterized by slowly rising water levels in the spring that flood shoreline vegetation by midsummer. These operations promote strong year classes by not dewatering spawning sites and by providing additional rearing habitat for young-of-year (YOY). A drawdown beginning in mid to late summer should occur to concentrate prey species and allow establishment of vegetation. Some articles further recommend substantial midsummer drawdowns periodically to re-establish vegetation that will increase fish habitat later in the year (Keith 1975, Wegener and Williams 1975).

While many studies have been performed, there is still a need for further research. Most of the previous studies (1) examined only short-term effects, (2) did not experimentally plan operational changes for fisheries, and (3) did not develop sampling strategies adequate to detect changes in the fish populations. Additionally, the biological mechanisms between reservoir operations and recruitment several years later are not clearly understood. For example, if prey or some other requisite of life is limiting, beneficial operations may produce strong year classes of sportfish that subsequently fail to recruit into the fishery.

An Evaluation of Existing Reservoir Data Sets

Existing reservoir databases were evaluated with the goal of gaining insight into the abiotic and biotic factors that could potentially influence sportfish standing crop. The previously mentioned subset of the National Reservoir Research Database and an unpublished data set of nutrient-related attributes were evaluated. Multiple regression procedures using a step-wise, maximum R^2 methodology (SAS 1985) were used to rank the importance of biotic and abiotic factors associated with the standing crop of sportfish.

Mean annual fluctuation was the abiotic factor in the data set most directly related to reservoir operations. When the data set was analyzed, mean annual fluctuation explained very little of the variability associated with standing crop of sportfishes

($r^2 = 0.03$) although the relationship was statistically significant ($p > 0.006$). In general, standing crop of sportfishes declined about 1.3 lb/acre for every foot of mean annual fluctuation. However, there were many reservoirs with substantial fluctuation that nonetheless had excellent sportfish populations, indicating that mean annual fluctuation is not a reliable predictor.

Nutrient-related biotic variables (phosphorus and nitrogen) explained much more about the standing crop of sportfish than did reservoir fluctuation. Fluctuation added little in a six-variable model including phosphorus- and nitrogen-related factors. Even when nutrient-related variables were modeled against standing crop of sportfishes, their predictive power was not very good. When a total of 10 nutrient-related variables were related to sportfish standing crop, R^2 values approximated 0.25. Such relationships indicate poor predictive power and suggest a need for experimental science to gain a deeper understanding of the effects of reservoir operations on the fishery resource.

Requirement for a Long-Term Case Study

A study site where reservoir operations could be altered solely for experimentation is necessary because of the limitations of existing studies. Most previous studies measured only short-term effects (Ploskey 1986), such as production of YOY, and did not follow these cohorts of fish for several years until recruitment into the fishery. Additionally, studies were frequently not replicated nor did they have efficient statistical designs to measure the benefits of enhanced operations.

A study site where the duration, onset, and magnitude of water-level fluctuations could be experimentally altered for 6 years is recommended. The reservoir needs to be of a typical size, approximately 10,000 to 30,000 surface acres. The reservoir design must be one that allows for efficient control of water levels so that it is not adversely affected by upstream operations. Unallocated water must also be available for experimental operations.

Fish populations and angling should be monitored prior to, during, and for 2 years after operational change. Operational changes should run sequentially with 2 years of existing or normal operations followed by 2 years of beneficial operation. A return to existing operations would follow for an additional 2 years.

Such a study design, along with intensive monitoring, would allow for replication and sufficient statistical precision to measure actual changes caused by operations. Water quality, prey populations, and sportfish would be monitored so as to gain insight into the mechanisms affecting recruitment. The magnitude of improvement in the fishery and the response of anglers would also be determined. This approach provides an estimate of the magnitude of benefits derived from enhanced operations and considers operational changes that would not benefit fisheries. Such information would allow decisionmakers within and outside the Corps of Engineers to make better choices as to operational strategies.

Summary of the Work Unit

The scientific literature was reviewed and major reservoir databases were analyzed. Physical data and standing crop information in the National Reservoir Research

Program Database were analyzed. This analysis included 253 reservoirs in the southeastern and midwestern United States where rotenone sampling was judged to be optimal in measuring standing crop of fishes. This analysis was performed using statistical procedures (SAS 1985) to gain familiarity with these databases and to confirm the findings of others.

The findings in earlier studies are likely correct. Factors such as nutrients and climate had a greater influence on standing crop of sportfishes than did magnitude of mean annual water-level fluctuation. Variability in standing crop was largely unexplained by parameters in the data. However, statistical analysis determined that mean annual water-level fluctuation negatively affected sportfish standing crop, which declined approximately a pound per acre for every foot of fluctuation. The predictive power of this relationship was poor ($R^2 = 0.03$), and some reservoirs with substantial mean annual fluctuation also had good sportfish populations.

Operations can significantly affect sportfish populations. However, examining mean annual fluctuation alone does not adequately explain operational effects on fisheries. The extent and duration of water-level changes may be more important than the magnitude of those changes. A broad-based approach suggested by Ploskey (1986), which benefits strong year class production of sportfish production, is probably appropriate. This approach needs to be validated by long-term field studies, preferably in several regions, to determine the extent that beneficial operations can improve angling. These experimental studies are also needed to document the extent that operations benefit fisheries and biological mechanisms associated with sportfish recruitment. Together, this understanding will allow resource managers to evaluate trade-offs between operations and the situations where altered reservoir operations may reasonably be expected to enhance fisheries.

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